Title
Wind Power Development in the United States: Current Progress, Future Trends

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Abstract:

The U.S. wind power industry is in an era of substantial growth, with the U.S. and China likely to vie for largest-market status for years to come. With the market evolving at such a rapid pace, keeping up with current trends in the marketplace has become increasingly difficult. At the same time, limits to future growth are uncertain. This paper summarizes major trends in the U.S. wind market, and explores the technical and economic feasibility of achieving much greater levels of wind penetration. China would be well served to conduct similar analyses of the feasibility, benefits, challenges, and policy needs associated with much higher levels of wind power generation than currently expressed in national targets.

Keywords: *Wind energy, renewable energy, cost trends, deployment*

1. Introduction

Global wind power capacity is growing at a rapid pace. Although European countries have led the charge over most of the past decade, the U.S. has led the world in annual capacity growth for three years running (2005-2007), followed by European stalwarts Germany and Spain, as well as the up-and-coming Asian markets of China and India. The technology has matured and, in good wind resource regimes, costs are comparable to fossil-fuel generation. Governments the world over are supporting continued growth through aggressive policy actions.

This paper begins with an overview of the U.S. wind power market. Drawing on the results of a recent report by the U.S. Department of Energy (Wiser and Bolinger 2008), this section emphasizes the growth and maturity of the U.S. wind market, as well as

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the positive economics of wind relative to its fossil-fueled competitors. To assess the feasibility of achieving much higher levels of wind power penetration, the paper then summarizes an analysis of the technical and economic viability of wind energy meeting 20% of U.S. electricity needs by 2030 (U.S. DOE 2008). The paper ends with a brief discussion of what is needed to achieve these higher levels of wind power deployment, as well as a call for similar analysis in China.

2. The U.S. Wind Power Market

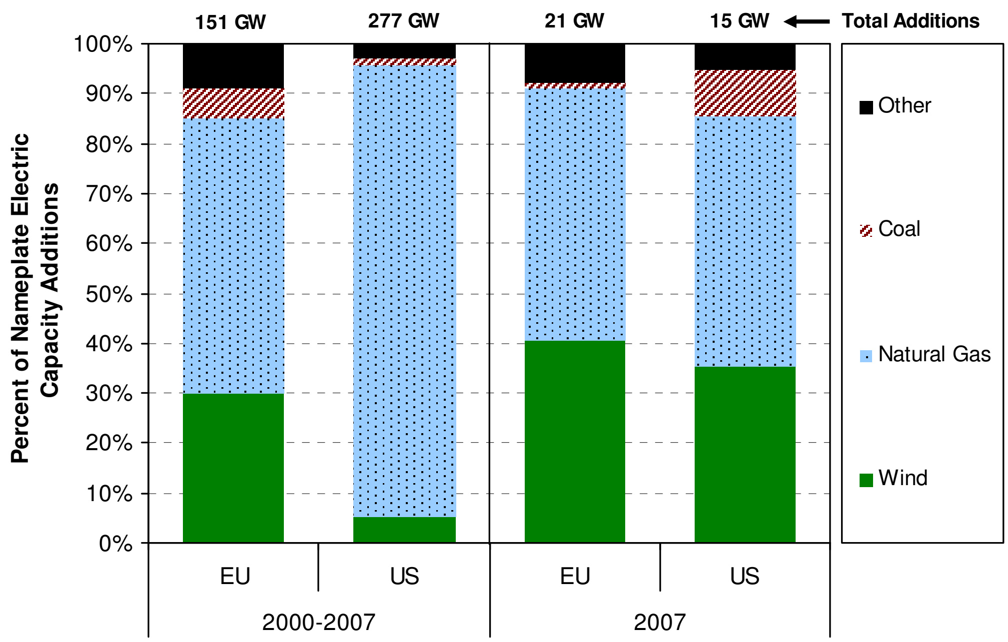
Nearly 20 GW of new wind capacity was installed worldwide in 2007, bringing the cumulative total to approximately 94 GW. For the third straight year, the U.S. led the world in 2007 in terms of newly installed wind capacity, adding in excess of 5.3 GW. This represented 27% of the worldwide wind market in that year, more-than-doubled the previous U.S. installation record set in 2006, and brought the cumulative U.S. total to roughly 17 GW (Table 1). And, with at least 225 GW of in-development wind projects in transmission interconnection queues at the end of 2007, the U.S. wind market is poised for continued strong growth in the years ahead.

Table 1. International Rankings of Wind Power Capacity

Incremental Capacity (2007, MW)		Cumulative Capacity (end of 2007, MW)	
United States	**5,329**	Germany	22,277
China	3,287	**United States**	**16,904**
Spain	3,100	Spain	14,714
Germany	1,667	India	7,845
India	1,617	China	5,875
France	888	Denmark	3,088
Italy	603	Italy	2,721
Portugal	434	France	2,471
United Kingdom	427	United Kingdom	2,394
Canada	386	Portugal	2,150
Rest of World	*2,138*	*Rest of World*	*13,591*
TOTAL	**19,876**	**TOTAL**	**94,030**

In both Europe and the U.S., wind now represents a major new source of electric capacity additions. From 2000 through 2007, wind was the second-largest new resource added in the U.S. (5% of all electricity capacity additions) and EU (30% of all electricity capacity additions) in terms of nameplate capacity, behind natural gas, but ahead of coal (Figure 1). In 2007, 35% of all capacity additions in the U.S. and 40% of all capacity additions in the EU came from wind power.

Figure 1. Relative Contribution of Generation Types to Capacity Additions in the U.S. and EU



Driving the growth in the U.S. are a number of factors, including promotional policies. In particular, 26 states now have renewables portfolio standards (RPS) in which electricity suppliers are required to source a certain fraction of their electricity from renewable energy. The federal government, meanwhile, continues to offer a 10-year, 2.1 cent/kWh production tax credit (PTC), though uncertainty in the fate of that policy has created a boom-and-bust cycle of wind development in the country. The prospect of future carbon regulations has also helped motivate wind additions in recent years.

Of equal importance to the aforementioned policy drivers has been the improved economics of wind power relative to fossil fuels which is – in part – dependent on wind project performance and installed costs. In the U.S., wind project performance has improved with time. In 2007, for example, wind projects in the U.S. had an average capacity factor of just over 31%. Those projects installed prior to 1998, however, maintained an average 2007 capacity factor of just 22%, while those projects installed from 2004 through 2006 averaged 34% (left-most graphic in Figure 2). Trends in the installed cost of wind projects are more mixed. Following movements in the overall power sector, the average installed cost for wind projects in the U.S. has increased significantly since the early 2000s, from $1,300/kW in 2001 to roughly $1,700/kW in 2007 (and to more than $2,000/kW in 2008) (real 2007$). Nonetheless, even at $2,000/kW, installed costs remain well below the $4,000/kW average seen in the early 1980s (right-most graphic in Figure 2).

Figure 2. Trends in the Performance and Installed Cost of Wind Projects in the U.S., By Date of Commercial Operation (COD)

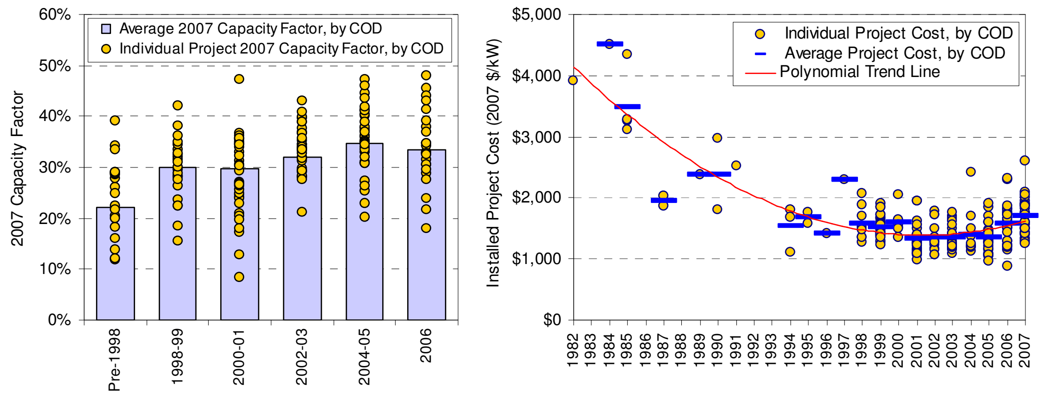
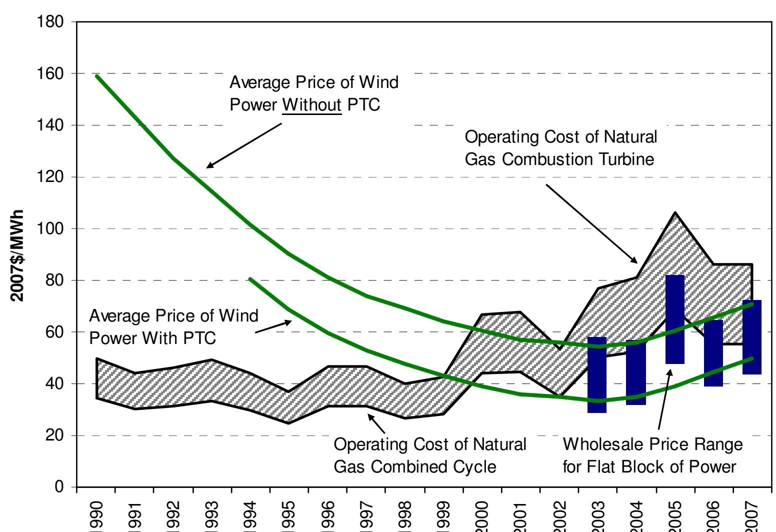


Figure 3 presents data on the resulting historical average price of wind power in the U.S., from 1990 to the present, both with and without the federal PTC. The figure also provides data on the annual fuel and variable operating cost of natural gas plants over this period, conservatively assuming that wind operates to conserve fuel and variable O&M, but that it does little to offset the need for new dispatchable power plants to maintain electricity reliability. Finally, the figure provides data on the price of a flat block of power across the numerous wholesale market trading hubs in the country from 2003 through 2007. Though clearly a simplified approach to comparing the economics of different energy sources, Figure 3 nonetheless shows that, since 2000, wind power with the PTC has often been economically competitive with other sources of electricity in the U.S. Moreover, though a confluence of factors has put upward pressure on wind power prices since the early 2000s, those cost pressures have affected other generation technologies as well. As a result, the relative economic position of wind has not changed dramatically over this period.

Figure 3. Comparative Economics of Wind, Natural Gas, and Wholesale Electricity Prices in the United States



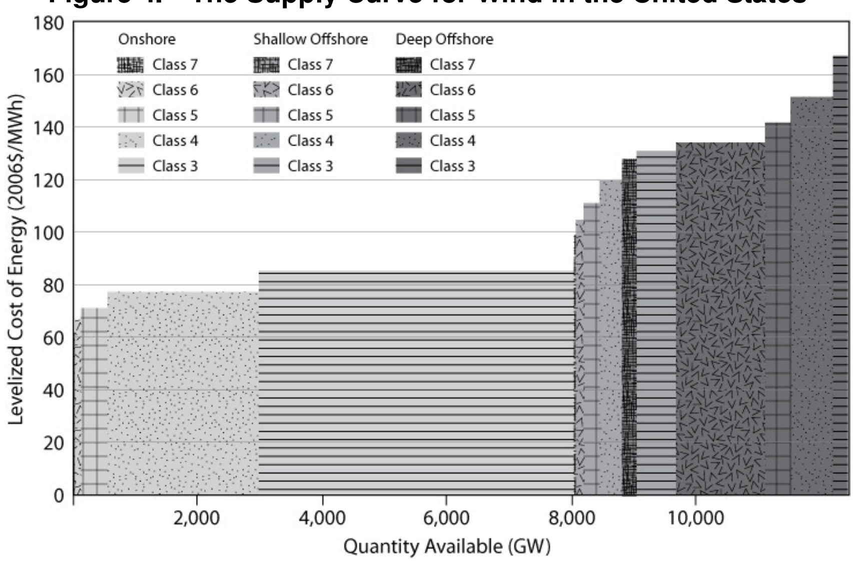
3. Analyzing the Possibility of 20% Wind Electricity

Despite these positive trends, wind capacity installed by the end of 2007 contributes just 1.2% of total U.S. electricity supply. Even with a continuation of recent growth, wind would remain a relatively small share of U.S. electricity supply for many years to come. To explore the possibility of more-aggressive levels of wind deployment, the U.S. Department of Energy, in collaboration with its national laboratories, and the wind industry, recently completed a major analysis of the technical and economic feasibility of wind power meeting 20% of the nation's electricity supply needs by 2030.

Not surprisingly, the study finds that reaching 20% wind would require a dramatic increase in wind capacity. In particular, 305 GW of wind capacity would be needed by 2030. The analysis projects that more than 50 GW of this capacity would be installed offshore. From 2018 to 2030, roughly 16 GW of wind would need to be installed annually, compared to the 5.3 GW added in 2007.

Though surely a daunting challenge, the analysis finds that the U.S. has vast wind resources, far exceeding what is needed to achieve 20%. Considering busbar economics alone, for example, and ignoring transmission and integration costs, Figure 4 provides a supply curve for wind using cost and performance assumptions from 2007. Even assuming that the PTC is not available, the study finds that roughly 8,000 GW of wind is potentially available at busbar generation costs of less than $85/MWh.

Figure 4. The Supply Curve for Wind in the United States

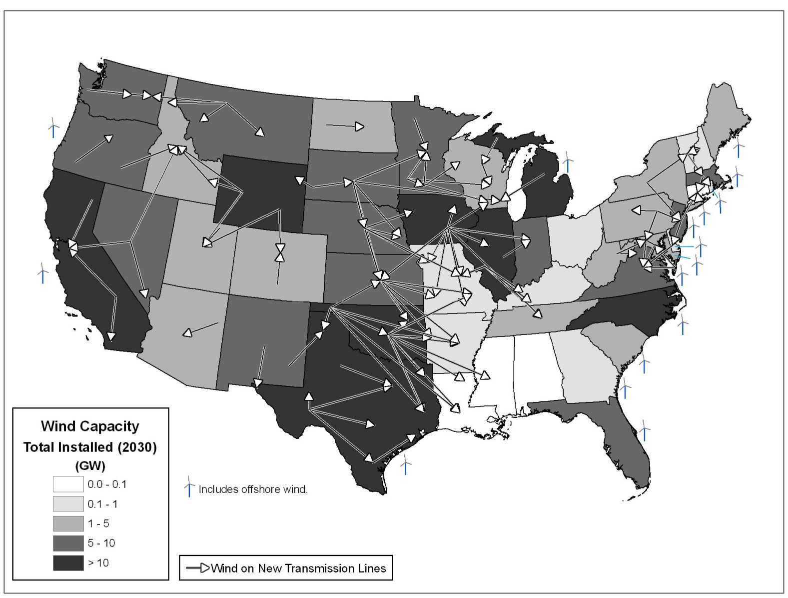


The analysis also shows that there are no fundamental physical limitations to raw material supplies (e.g. sand, cement, iron ore), though the potential for shortages of processed materials like fiberglass or steel does exist and may have to be overcome. This level of growth would also require a substantial labor force. A key challenge to reaching 20% will be to maintain downward pressure on installed wind project costs while the industry rapidly expands.

The study further concludes that, although sufficient land area exists, siting challenges will be significant. Figure 5 illustrates the potential location of the 305 GW of wind, based on the economic modeling conducted for the study. As shown, wind capacity additions occur in almost every state. Assuming that the projected land-based wind turbines are all located in one wind plant, that plant would cover a square roughly 225 km (140 miles) on a side, or roughly 0.5% of total U.S. land area. Only 2-5% of this area would be occupied by turbine towers, roads, etc. Nonetheless, concerns about wildlife impacts, aesthetics, and other factors will surely need to be addressed in order to achieve this level of capacity additions.

Because the best wind resources tend to be long distances from population centers, expansion of the nation's transmission infrastructure is an essential precondition for achieving high levels of wind penetration. Figure 5 presents one broadly suggestive scenario for the wind energy transfer between regions, based on modeling output. The 20% Wind scenario projects the addition of approximately 12,000 miles of new transmission lines at a discounted cost of about $20 billion. Although the $20 billion cost estimate is not prohibitive from the perspective of the overall electric sector, the institutional barriers to planning, siting, and recovering the cost of this quantity of new transmission lines are not insubstantial, and transmission expansion may pose the most significant challenge to achieving high levels of wind generation.

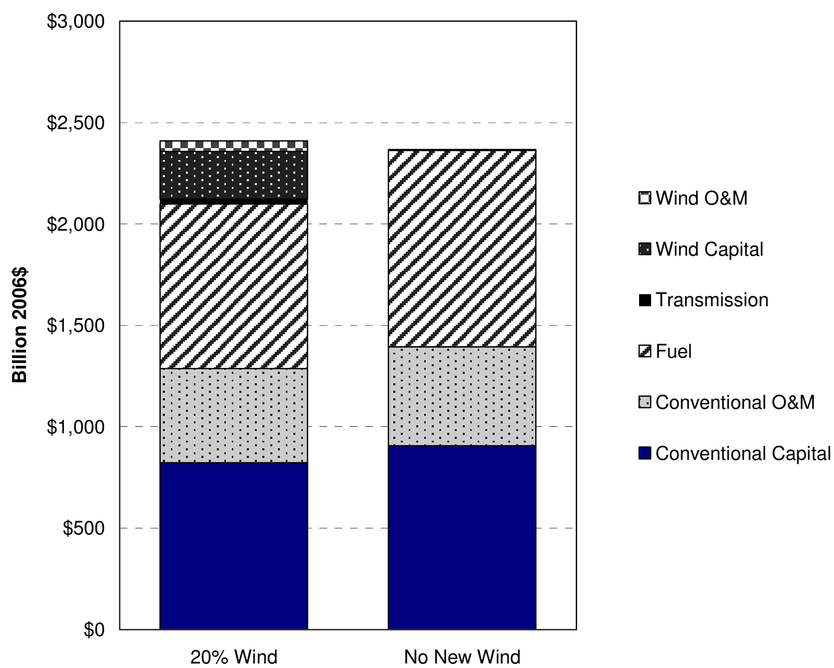
Figure 5. Installed Wind Capacity by State in 2030, and New Transmission Needs



Importantly, the study also concludes that the integration of 20% wind into U.S. electricity markets is both technically and economically feasible. In contrast to many other sources of electricity, wind power is inherently variable and non-controllable. Despite these characteristics, a growing number of studies indicate that high levels of wind penetration can be accommodated as part of interconnected power systems. Though accommodating wind requires modifications to power systems planning and operations, the costs imposed by these changes are generally found to be below $10/MWh for wind penetrations of up to 20%. One key output of the modeling conducted for the 20% wind study is that the increased wind generation offsets both coal and combined-cycle natural gas usage, but also leads to a significant increase in quick-ramping gas combustion-turbine capacity in order to maintain system reliability.

At the heart of the analysis was an assessment of the economic feasibility of achieving 20% wind, and here the news is positive: if the significant institutional barriers can be overcome, the overall incremental costs of achieving 20% wind energy are projected to be relatively modest. Figure 6 shows the total estimated electric-sector costs for both the 20% Wind and the No New Wind scenarios. In aggregate, the 20% Wind scenario imposes an estimated net discounted incremental cost of over $40 billion. This implies an average incremental cost of wind (compared to the fossil generation otherwise deployed) of $9/MWh, an average increase in retail electricity rates of $0.6/MWh, and a bill impact for an average household of roughly $0.50 per month. Subsequent technical analysis has explored the sensitivity of this cost to differing input parameters, and has found the cost estimate to be relatively robust.

Figure 6. Total Electricity-Sector Direct Costs (discounted at 7%/yr)



Of course, these direct costs are offset by a number of *possible* benefits, including lower fossil-fuel prices, environmental improvement, reduced water consumption, rural economic development, and employment opportunities in the renewable energy sector.

Perhaps most importantly, achieving 20% wind would reduce the carbon footprint of the electricity sector. In particular, analysis shows an annual reduction of 225 million metric tons of carbon by 2030, equivalent to roughly 20% of expected electricity-sector carbon emissions in 2030. The carbon reductions are estimated to come at a cost of $13/tCO2-eq, well below the price range estimated by the Intergovernmental Panel on Climate Change to be needed even in moderate carbon reduction regimes.

4. Conclusions

Wind power has become a mainstream energy source in the United States, and further growth is expected. The wind resource is vast and, though accessing this potential is not costless or lacking in barriers, wind power can be developed at what many would consider to be an acceptable cost. To grow wind at scale, however, a "business as usual" path will not do. In addition to stable, long-term financial incentive policies, the following actions are likely to be needed:

1. Dramatically expanded transmission investments specifically designed to access remote wind resources.
2. Larger power control regions, better wind forecasting, and increased investment in fast-responding generating plants to effectively integrate wind into electricity grids.
3. Streamlined siting and permitting procedures that allow developers to identify appropriate project locations and move to project construction quickly.
4. Enhanced research and development to lower the cost of offshore wind power, and incrementally improve conventional onshore wind technology.
5. Investments in technologies that may enable even greater penetration of wind, including storage, plug-in hybrids, demand response, and hydrogen production.

The potential benefits, costs, opportunities, and challenges to achieving higher levels of wind penetration in China may be somewhat similar to those in the U.S. But, China's conditions are unique, and the country would be well served to conduct further assessments of the technical and economic feasibility of achieving higher levels of wind deployment. Moreover, especially if higher deployment targets are developed, it is critical that policy measures be targeted towards removing the barriers to that deployment. Such measures surely include economic incentive policies. However, transmission policy, siting policy, and grid integration issues must also be high priority items; incentive policies alone are not likely to be sufficient to pave the way for an electricity system that relies heavily on wind.

5. References

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